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Title: Dry Cask Storage Verification with Muon Radiography

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Dry Cask Storage Verification with Muon Radiography

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Spent Fuel in Dry Cask Storage

- Increasing amounts of spent fuel are being placed in dry casks for long term storage
- This fuel presents a potential proliferation risk if diverted for plutonium reprocessing

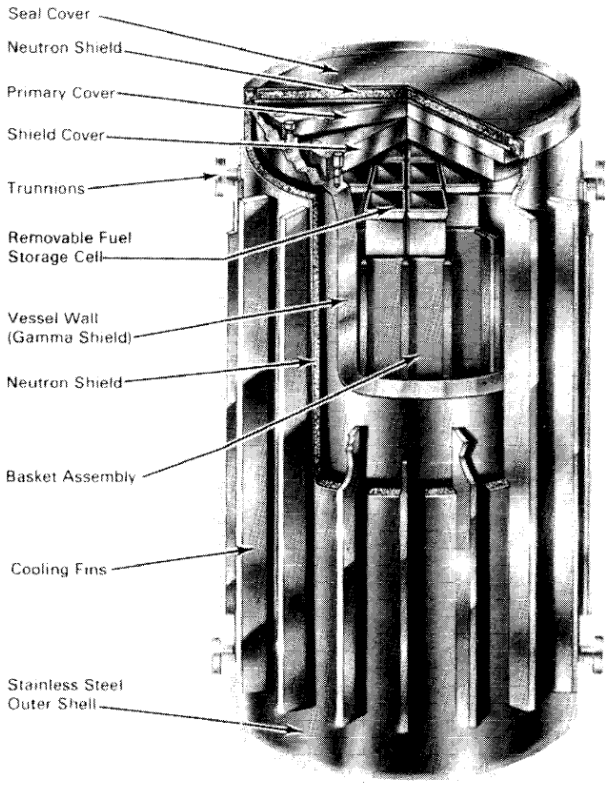
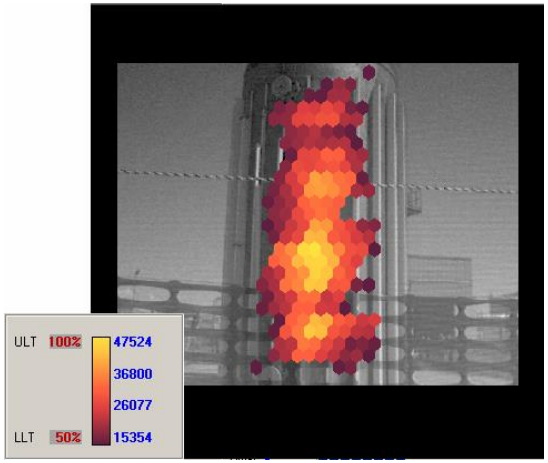
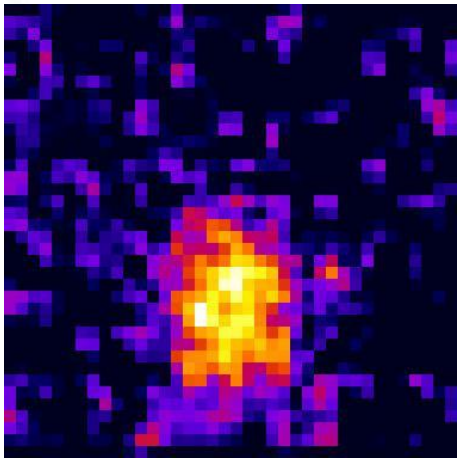


Figure S-1. MC-10 Spent Fuel Storage Cask

The cask's heavy shielding precludes detailed radiographic inspection by typical probes



Gamma ray image



Neutron image

Ziock et al, *IEEE Nuclear Science Symposium Conference Record* , vol.2, no., pp.1163,1167, 23-29 Oct. 2005

Currently, the only viable method of verification is opening cask for visual inspection.
-Costly, invasive, time-consuming, potentially dangerous

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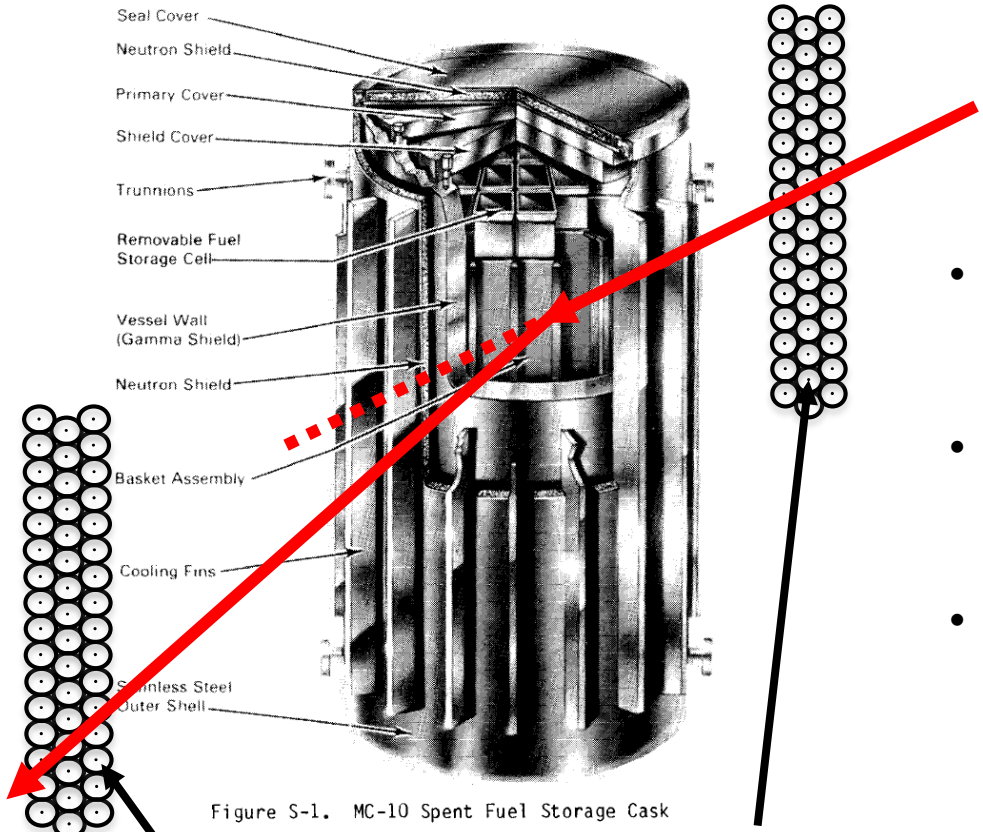


Figure S-1. MC-10 Spent Fuel Storage Cask

A new technique: muon multiple scattering radiography

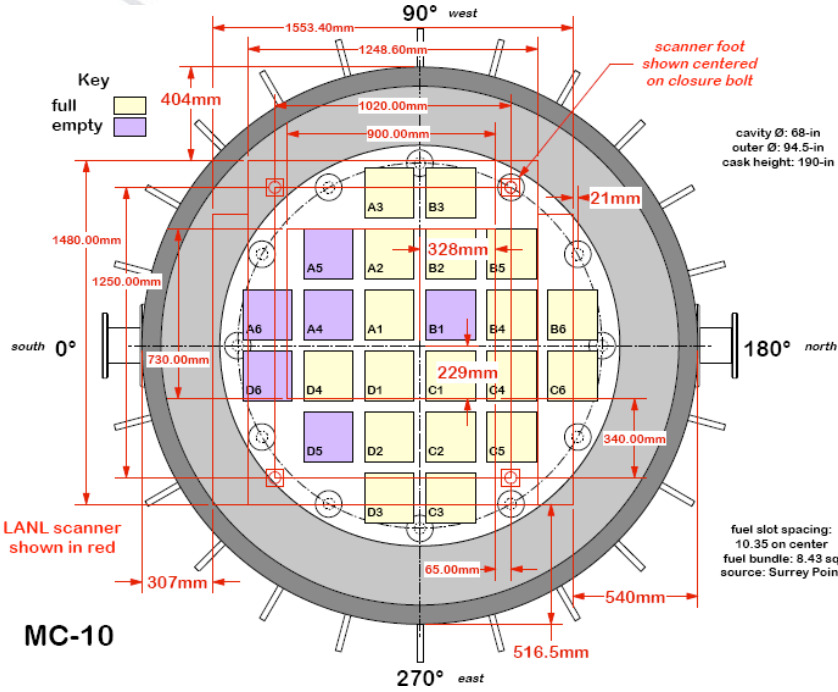
- **Cosmic ray muons impinge on the Earth at a rate of ~1/cm^2 per minute**
- **Capable of penetrating through many meters of steel/lead/concrete shielding**
- **Scattering angle is dependent on Z of material muon passes through**

Layers of drift tubes record muon position and trajectories before and after passing through cask

Measurement Setup at INL

Muon trackers in weatherproof enclosures. One side elevated to increase muon flux through both detectors (falls off as ~$\cos^2\Theta$).

Westinghouse MC-10 cask



Cask loading profile. Several fuel bundles are missing. The bundles are high-burnup PWR fuel, removed from commercial plants in early 80s.

Count time: 100 hrs

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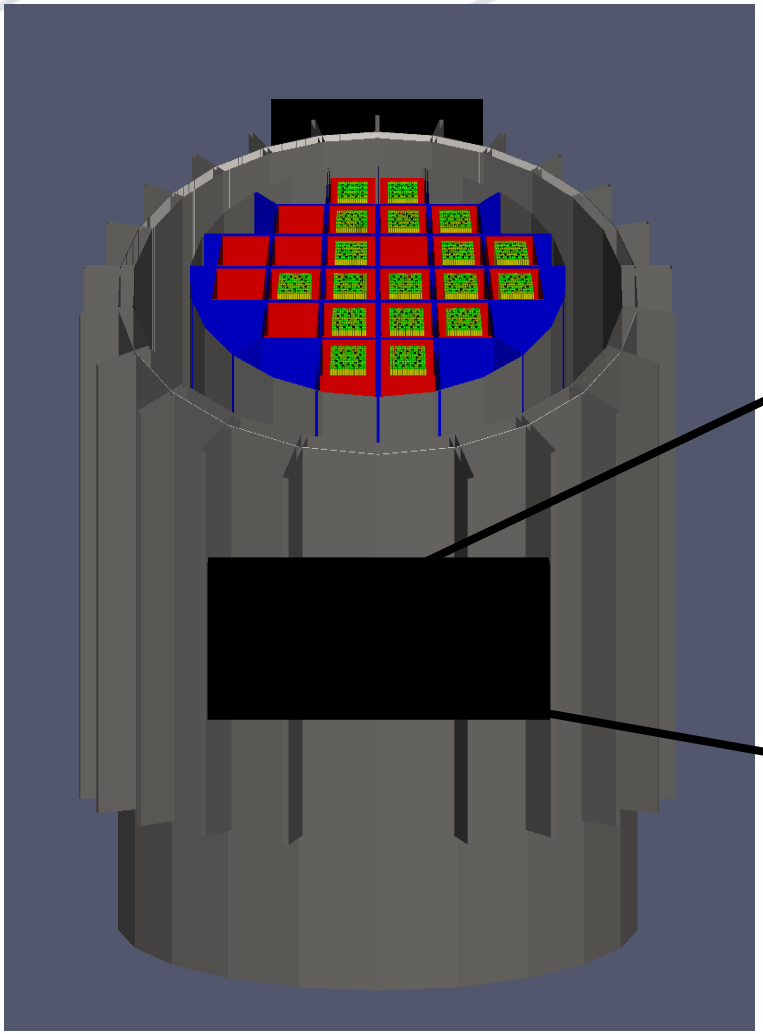
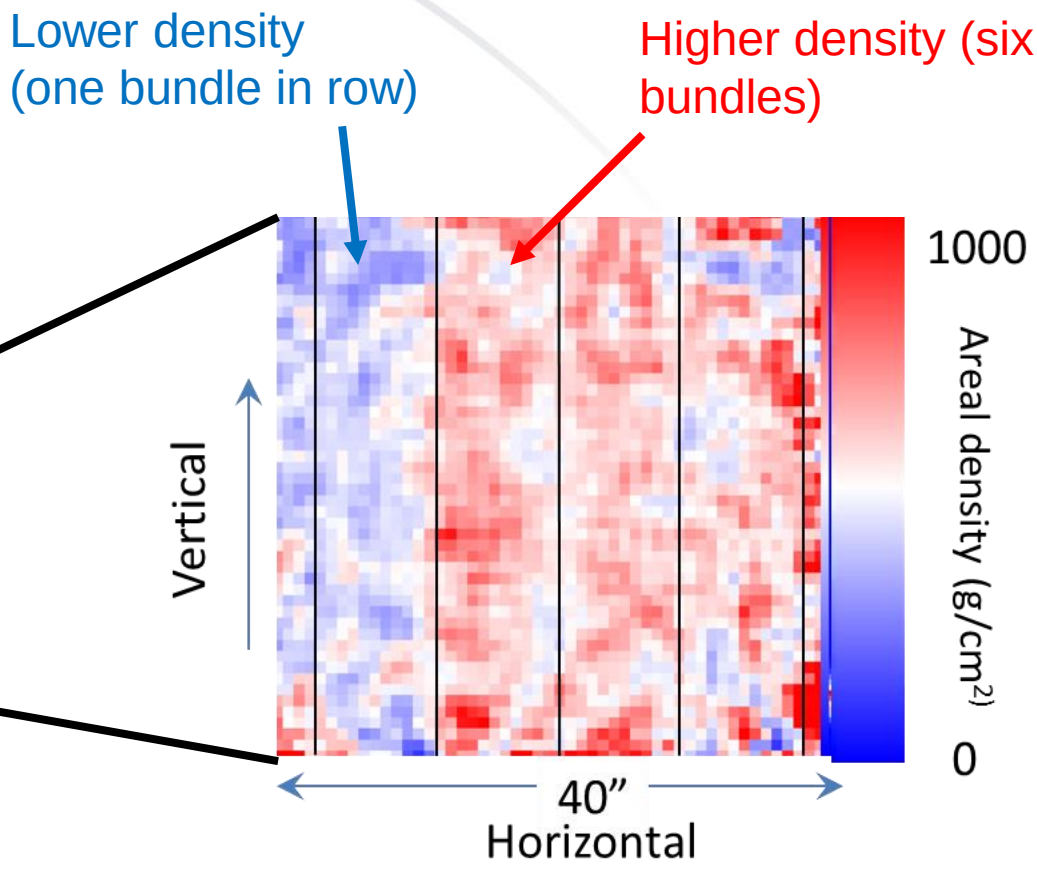
Preliminary Results





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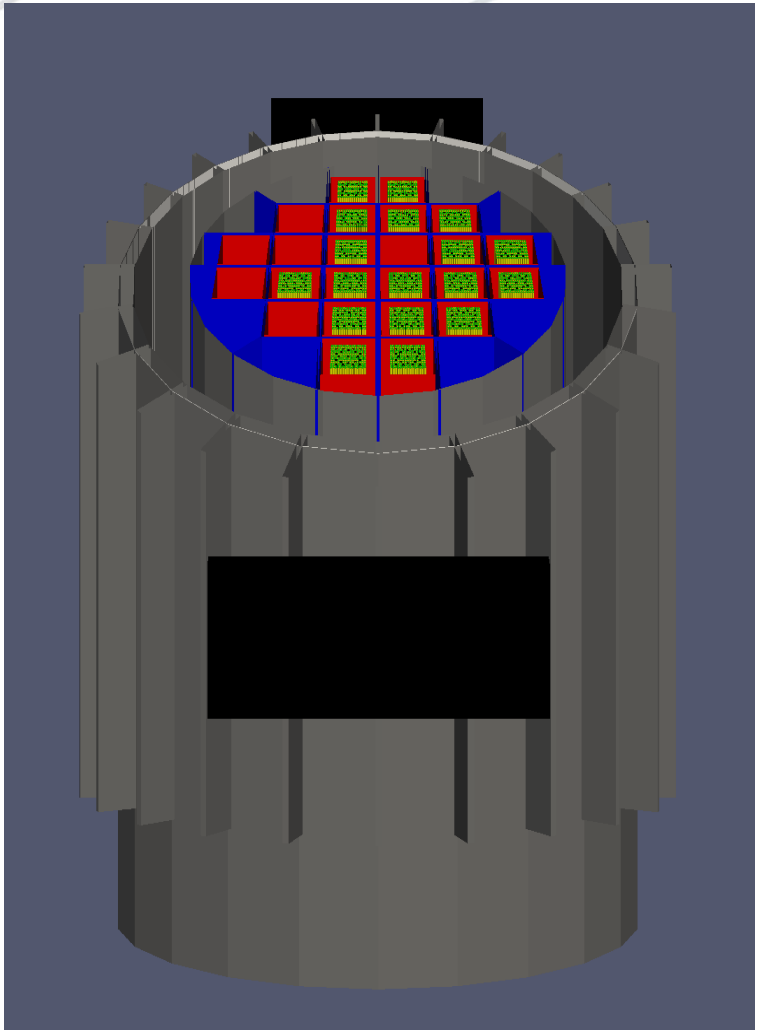
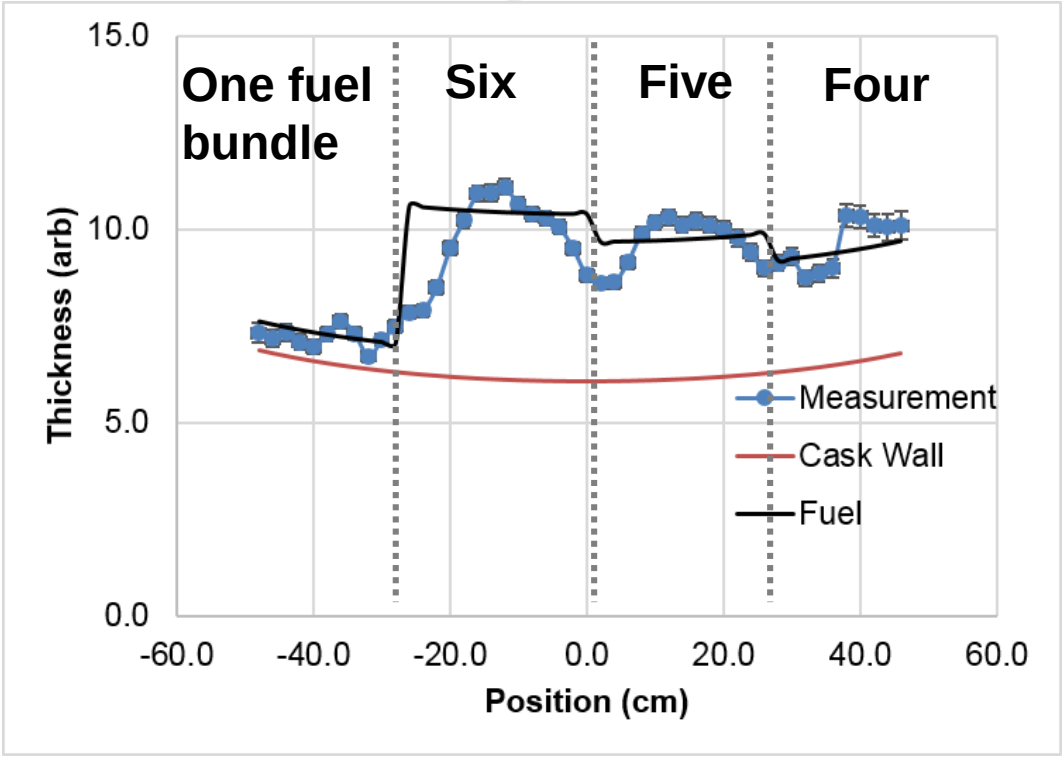


Integrated Thickness



Summary

- Cosmic ray muons can penetrate significant shielding that defeats typical radiographic probes.
- Preliminary results on identifying partial defects in dry cask contents are promising.
- Further modeling and data analysis are underway.

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NA-22 Office of Weapons and Materials Security

BACKUPS

Muon Radiography – Imaging with Natural Cosmic Radiation

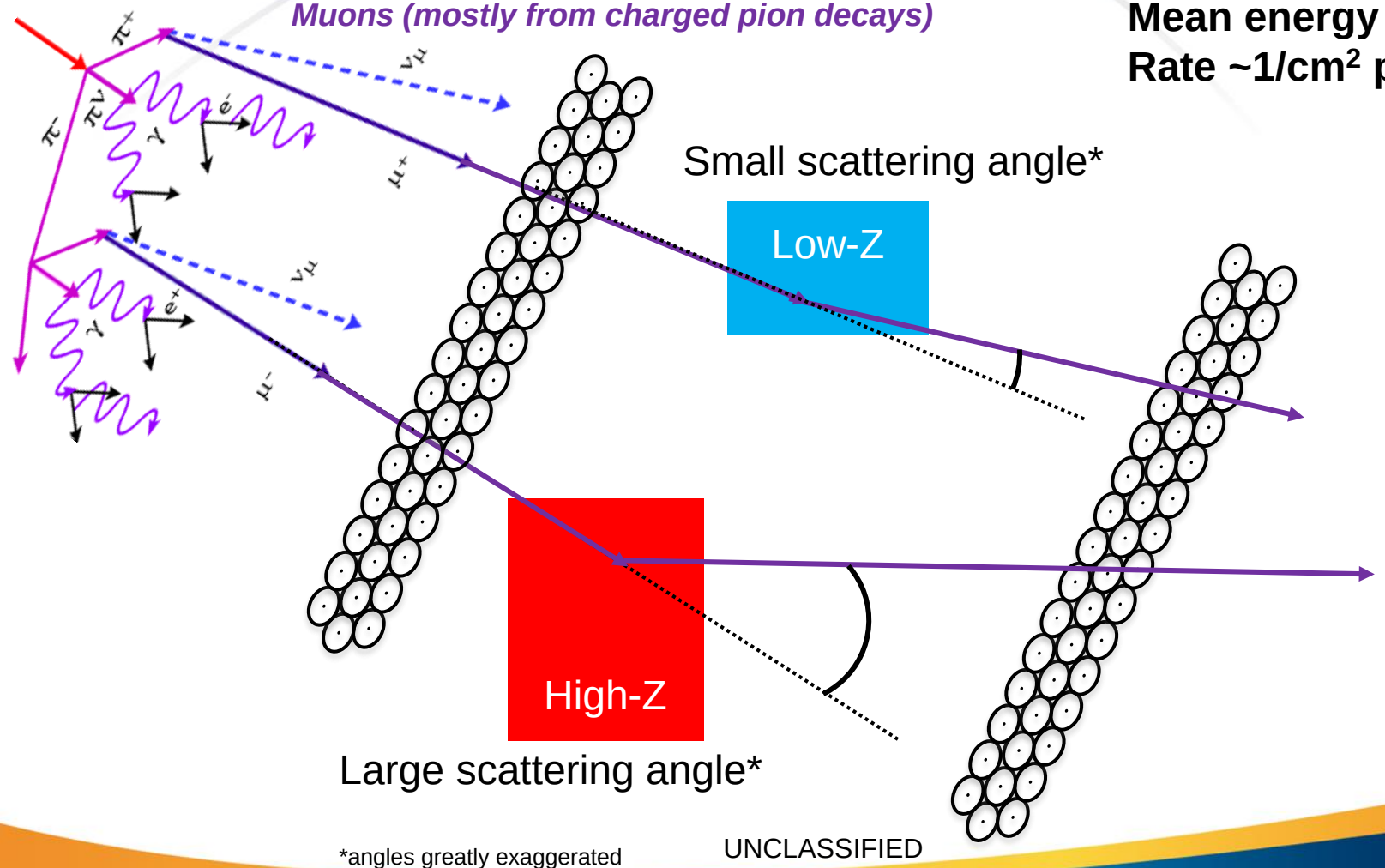
Los Alamos NATIONAL LABORATORY EST. 1943

High-energy primary cosmic ray

Short-lived secondary particles (mostly pions)

Muons (mostly from charged pion decays)

Muon mass ~200 $m_{electron}$
Mean energy ~3 GeV
Rate ~1/cm² per minute



*angles greatly exaggerated

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